PLANE FAILURE

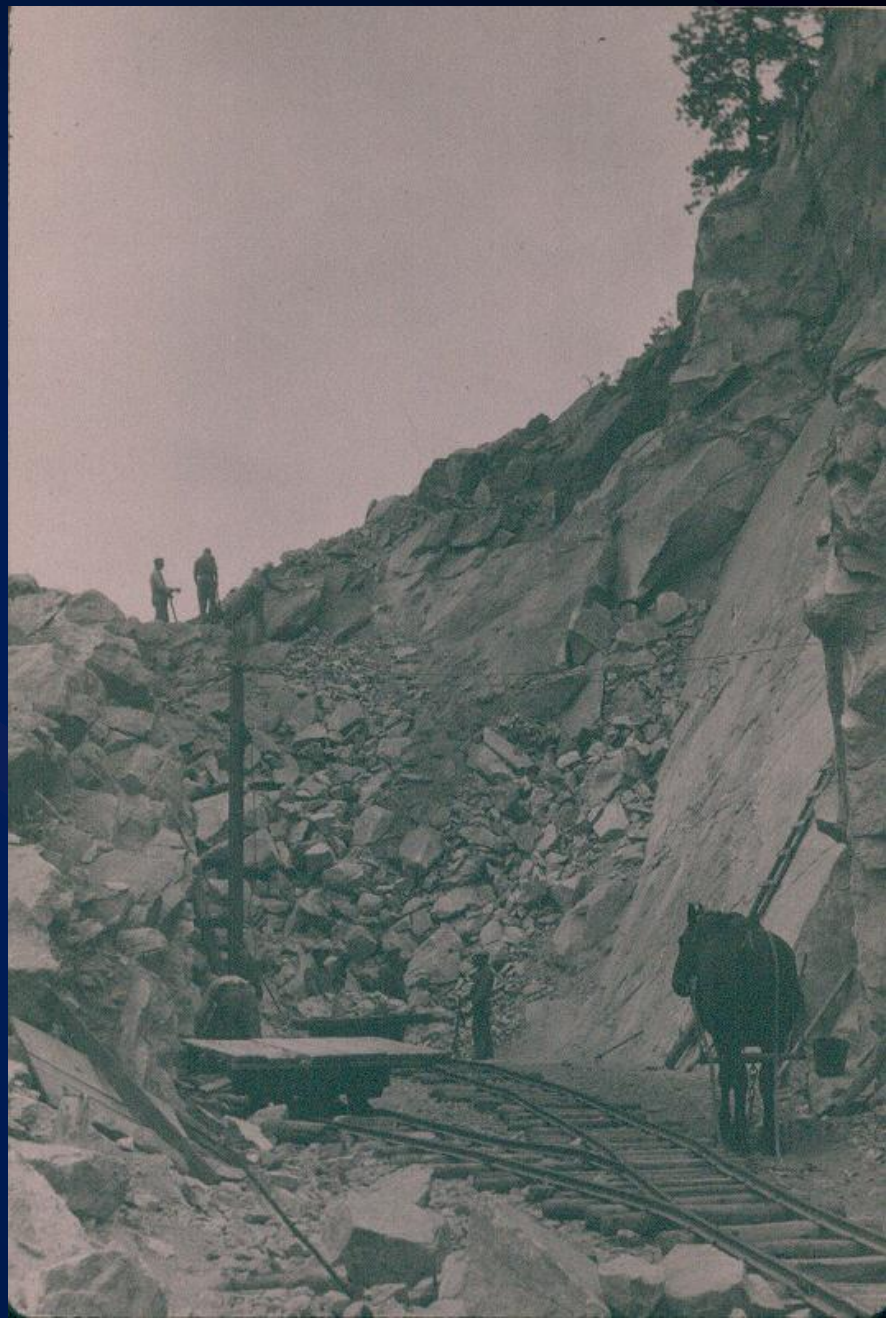
Lesson 5

LESSON 5 – ANALYSIS of PLANE FAILURE

Learning Outcomes -

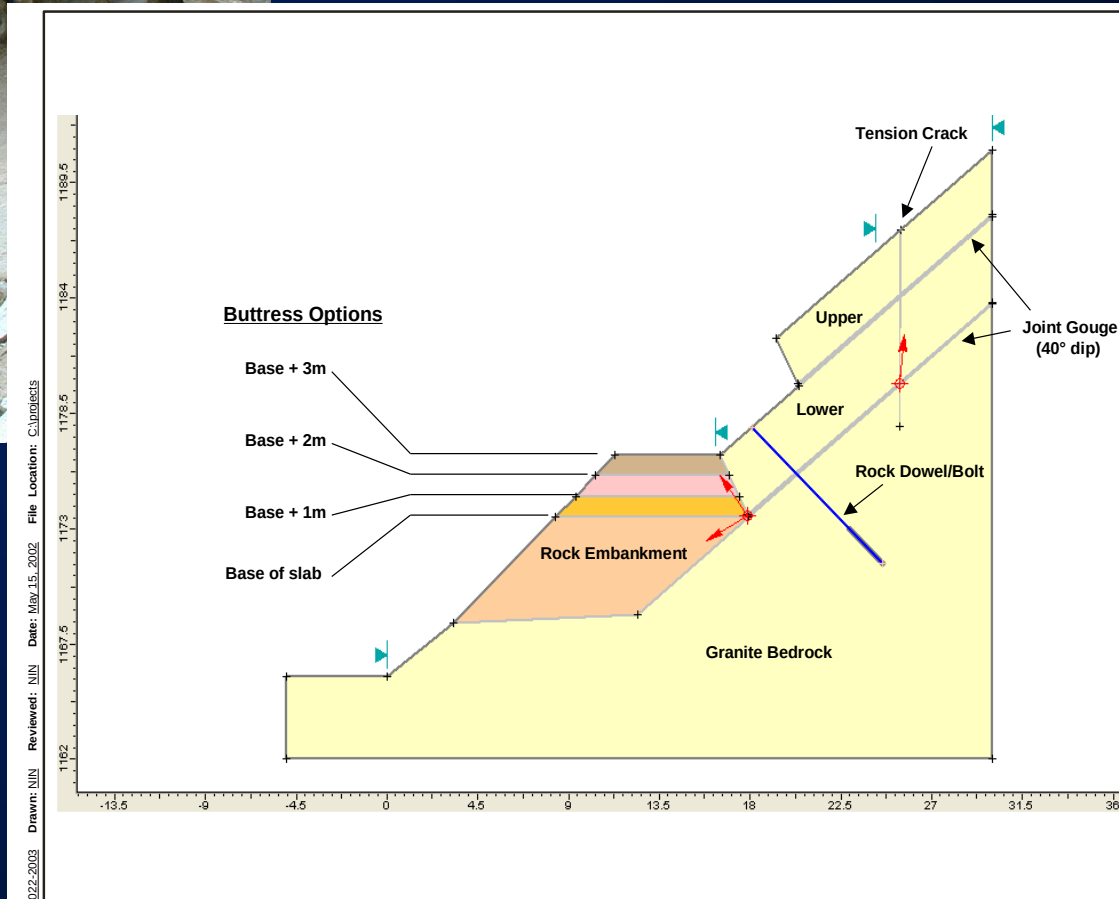
- Analyze structural geologic and slope geometric conditions using stereonets;
- Analyze for factor of safety using standard formulae for Planar Failure;
- Determine critical tension crack location and depth.

“Textbook example”




Bedding plane failure

Classic plane failure on persistent, smooth joints



Curved planar failure

Asymmetric plane failure

Conditions for Plane Failure

- Sliding Plane Parallel to Slope Face
- Sliding Plane "Daylights" on Face
- Sliding Plane Dips > ϕ
- Release Surfaces at Sides of Block

Conditions for Plane Failure

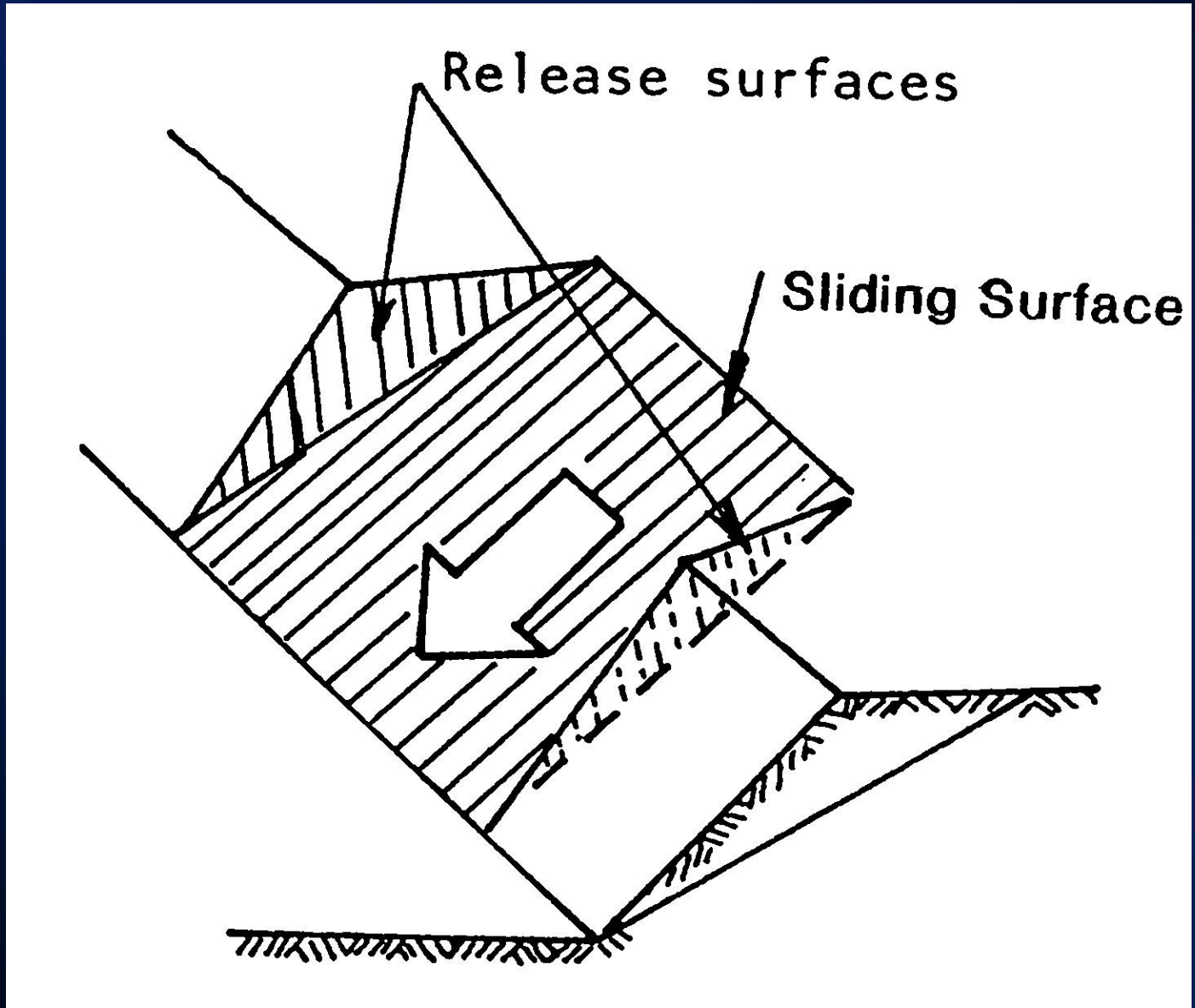


Fig 5-1


Release surfaces
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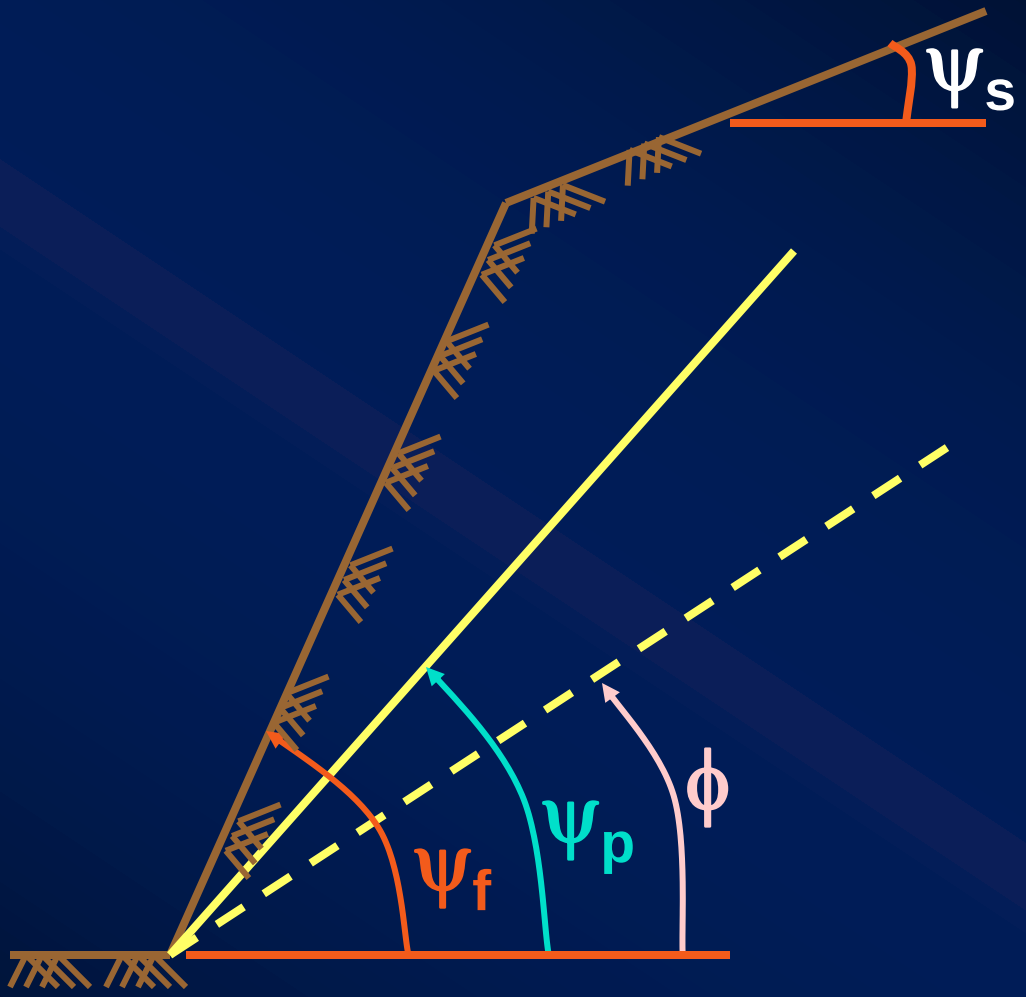
Release surfaces

Conditions for Plane Failure



For Sliding

$\psi_f > \psi_p > \phi$

Fig 5-1

Factor of Safety Calculation

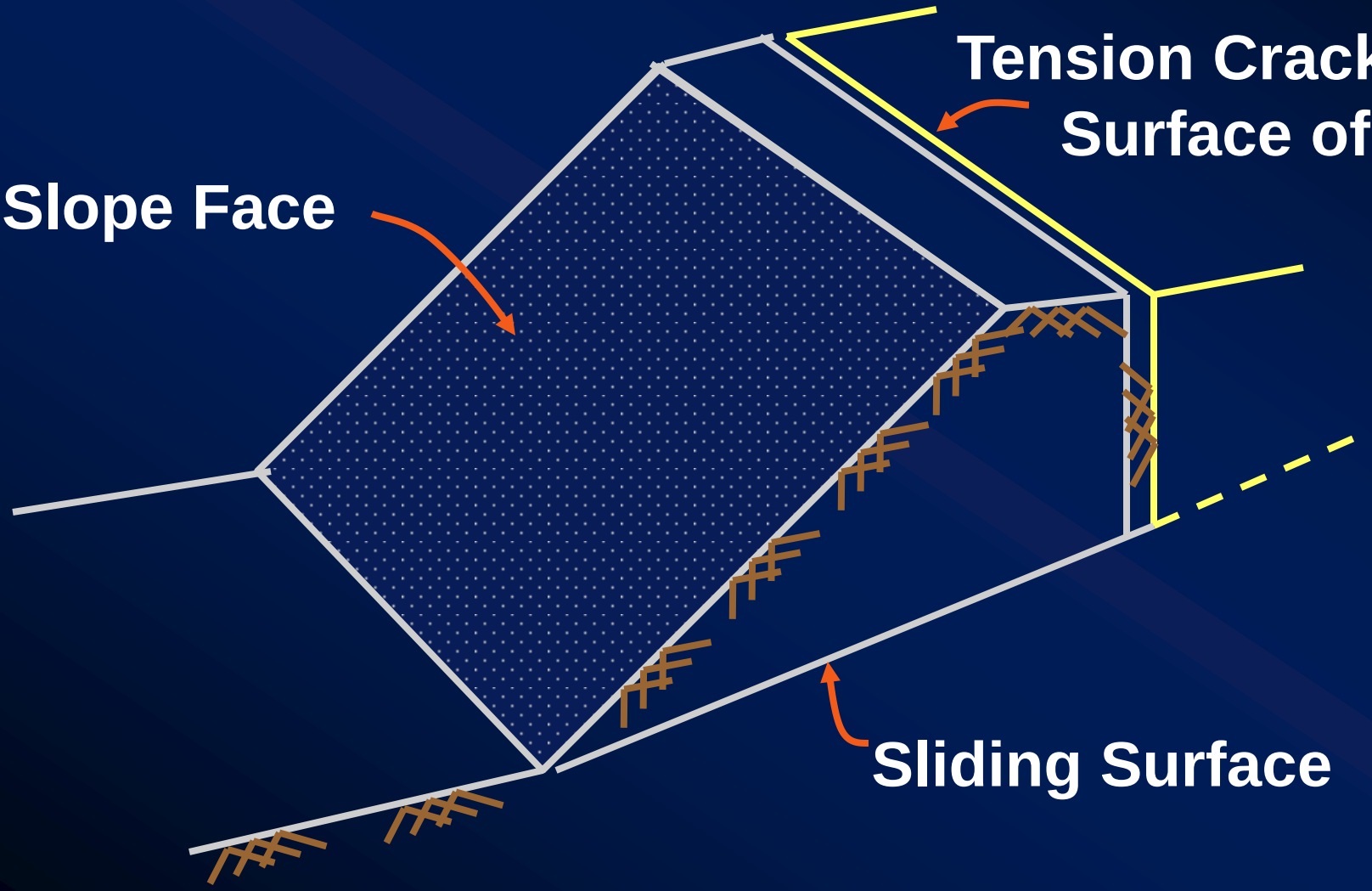


Fig 5-2

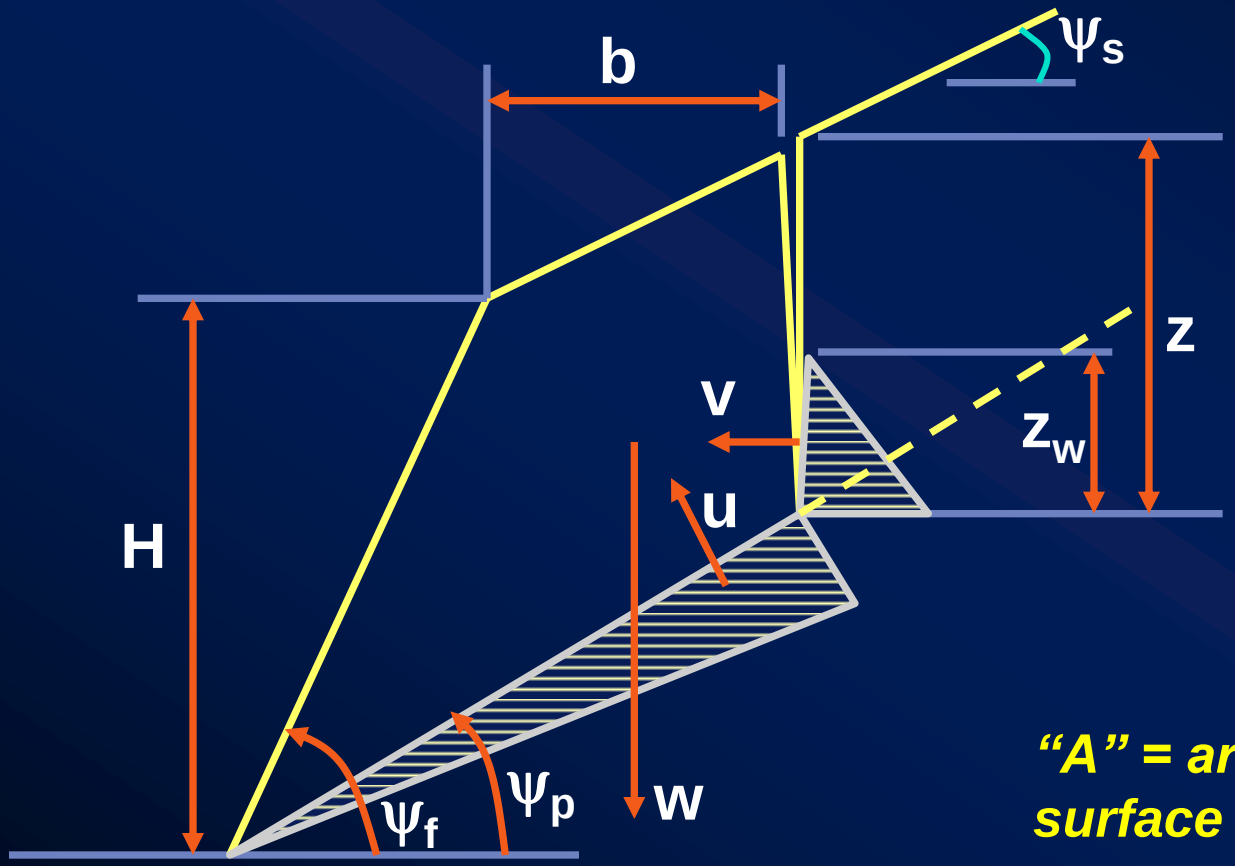
Plane Failure Analysis Assumptions

- *Sliding Plane & Tension Crack Parallel to Face*
- *Tension Crack Filled with Water to Depth zw*
- *Water Pressures - Triangular Distributions*
- *Forces Act Through C. of G.*
- *Shear Strength - Cohesion and Friction Angle*
- *No Resistance to Sliding on Side Release Surfaces*
- *Slice of Unit Thickness*

Factor of Safety Calculation

$$F = \frac{cA + (W\cos\psi_p - U - V\sin\psi_p)\tan\phi}{W\sin\psi_p + V\cos\psi_p}$$

(Eqn 5-2)



"A" = area of sliding surface

Spreadsheet Analysis

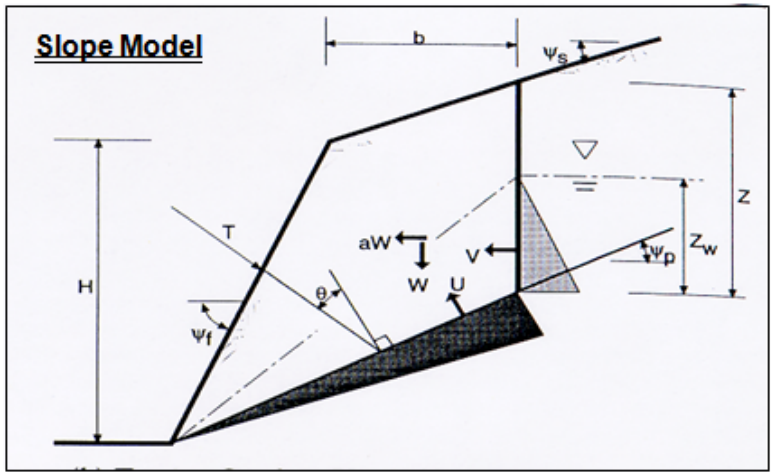
PLANE FAILURE ANALYSIS

wyllie & norrish ROCK ENGINEERS

INPUT VARIABLES

Slope height,	H	100	ft
Tension crack distance,	b	16.4	ft
Water depth,	Z_w	14.5	ft
Rock unit weight,	γ_r	155	pcf
Water unit weight,	γ_w	62.4	pcf
Friction angle,	ϕ	20	deg
Cohesion,	c	200	psf
Slope angles:			
Upper slope,	ψ_s	34	deg
Base plane,	ψ_p	20	deg
Slope face,	ψ_f	76	deg
Slope Reinforcement:			
Bolt/cable force,	T	-	lb/ft
Bolt inclination,	ψ_T	15	deg
Bolt inclination to normal,	θ	55	deg
Seismic/Blast Acceleration:			
Fraction gravity,	α	0	g

Slope Model



CALCULATED VALUES

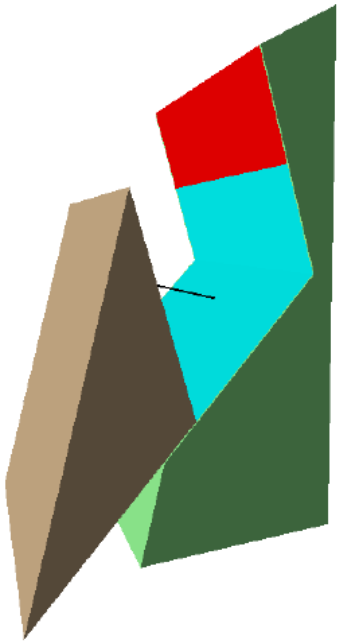
Tension crack depth,	Z	96.02	ft.
Weight of wedge,	W	413,299	lb.
Length of failure surface,	A	43.99	ft.
Hydrostatic uplift force,	U	19,899	lb.
Tension crack force,	V_n	2,244	lb.
Tension crack force,	V_p	6,164	lb.
Resisting force,	R	142,094	lb.
FACTOR OF SAFETY, F.S .=		**0.96**	

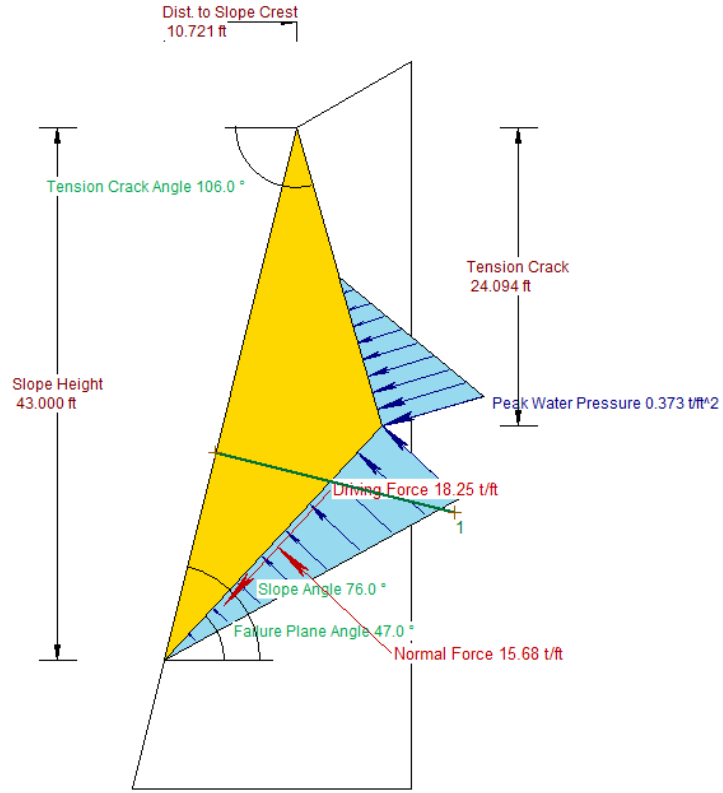
Commercial Software

Filename: Sector VI.pln
Project Title: RocPlane - Planar Wedge Stability Analysis

RocPlane Analysis

Document Name: Sector VI.pln
Job Title: RocPlane - Planar Wedge Stability Analysis
View: PERSPECTIVE
Safety Factor: 0.870264



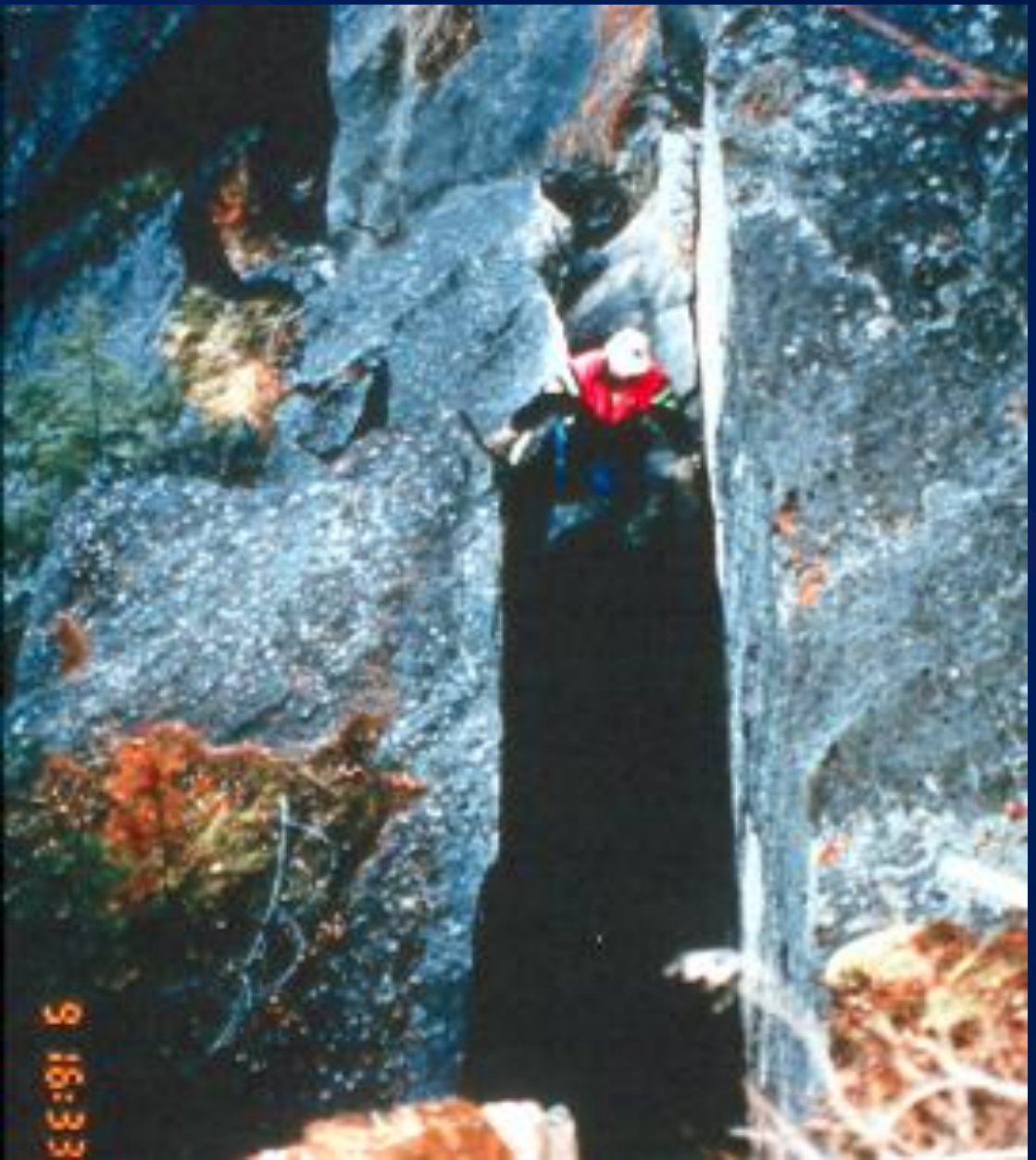


Factor of Safety	0.87
Driving Force	18.25t/ft
Resisting Force	15.89t/ft
Wedge Weight	22.22t/ft
Wedge Volume	277.70ft^3/ft
Shear Strength	12.25t/ft^2
Normal Force	15.68t/ft
Plane Waviness	0.0°
Active Bolt Force	0.00t
Active Bolt Angle	0.0°
Passive Bolt Force	7.50t
Passive Bolt Angle	346.0°
Water Force on Failure Plane	4.83t/ft
Water Force on Tension Crack	2.34t/ft

Bolt Properties:

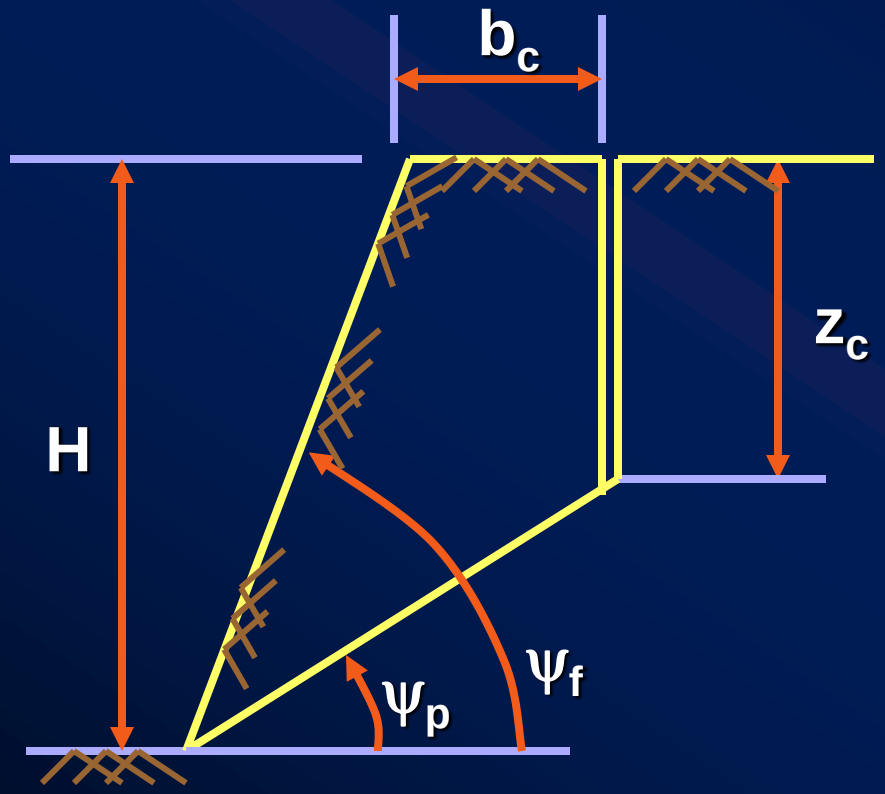
#	Angle	Capacity	Length	AnchLength
1	14.0 °	7.50t/ft	20.000 ft	10.371 ft

Tension Cracks – Red warning flag



Critical Tension Crack Location

- *Figure 5.5 Relates Depth (a) and Location (b) of Tension Crack to Slope Geometry*



Effect of Ground Water on Stability

- **Water Force V Acts in Tension Crack**
  - Adds to Driving Force

$$V = \frac{1}{2}\gamma_w \times Z^2_w \qquad \text{(Eqn 5-5)}$$

- **Water Force U Acts on Sliding Surface**
  - Decreases Normal Force

$$U = \frac{1}{2}\gamma_w \times Z_w (H + b\tan\psi_s - Z) \times \text{con}\sec\psi_p \qquad \text{(Eqn 5-4)}$$

Slope Reinforcement with Tensioned Rock Bolts

- *Rock Bolts Anchored Below Sliding Surface and Tensioned Against Face.*

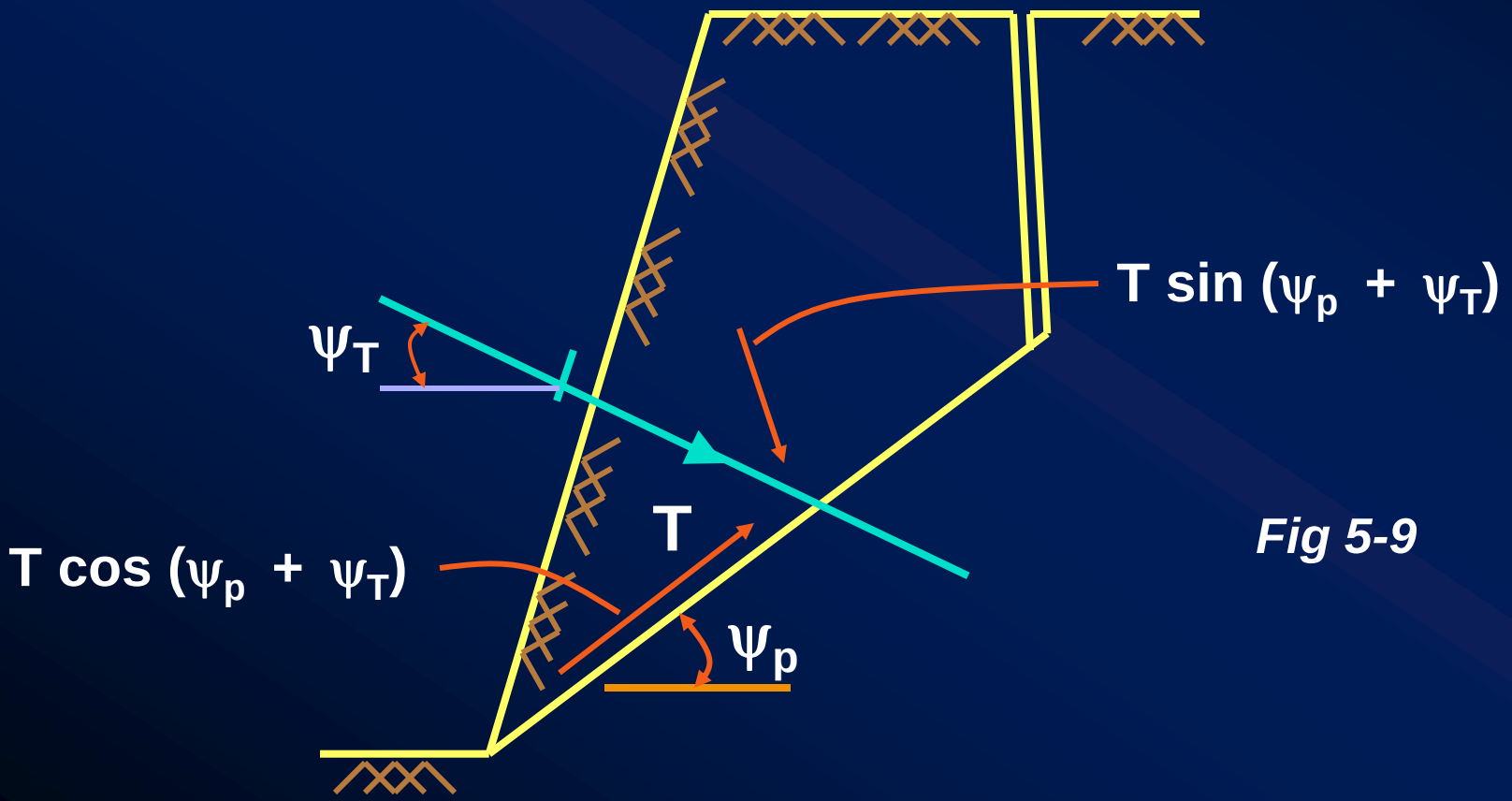


Fig 5-9

Reinforcement with Tensioned Bolts

- **Bolt Tension Increases Normal Force and Decreases Driving Force**

$$F = \frac{cA + (W\cos\psi_p - U - V\sin + T\sin(\psi_f + \psi_P))\tan\phi}{W\sin\psi_p + V\cos\psi_p - T\cos(\psi_T + \psi_P)} \qquad \textit{(Eqn 5-17)}$$

- **Optimum Bolt Orientation $\psi T(OPT)$**

$$\phi = (\psi_{T_{(OPT)}} + \psi_P) \text{ or } \psi_{T_{(OPT)}} = (\phi - \psi_P) \qquad \textit{(Eqn 5-18)}$$

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